2003

The effects of signals on responding during delayed reinforcement

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THE EFFECTS OF SIGNALS ON RESPONDING DURING DELAYED REINFORCEMENT

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Doctor of Philosophy

in

The Department of Psychology

by
Michael E. Kelley
B. S., St. Joseph’s University, 1995
M. A., Louisiana State University, 1999
May 2003

Acknowledgements

I thank the following individuals for their contributions to my education in School Psychology and Applied Behavior Analysis: Wayne Fisher, Joseph Lalli, F. Charles Mace, George Noell, John Northup, Cathleen Piazza, Henry Roane, and Joseph Witt. I also thank Constance Kelley for her contributions to my education in everything else I’ve learned. Finally, I thank Dorothea C. Lerman for her invaluable guidance during my graduate education. I dedicate this dissertation to the memory of Mary Devlin.

Table of Contents

Abstract

Functional communication training (FCT) is a commonly used intervention for severe behavior disorders (e.g., Carr & Durand, 1985; Wacker et al., 1990). This treatment is designed to provide individuals with developmental disabilities with a repertoire of responses to attain reinforcement. However, caregivers may be unable or unwilling to provide immediate reinforcement when the treatment is implemented in the natural environment. Recent applied research on responding during delayed reinforcement suggests that responding may not persist when delays exceed 30 s (e.g., Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hanley, Iwata, & Thompson, 2001). In contrast, results of basic research suggest that providing signals during delays may attenuate decrements in responding. The purpose of the current study was to evaluate the extent to which signals may influence responding when the delays to reinforcement are gradually increased over time. In Experiment 1, two individuals were exposed to gradually increasing delays in the context of a multielement design. The presence of a signal did not produce higher response rates or greater response persistence than when a signal was not present. For a third participant, baseline response patterns suggested

interaction effects would have influenced her behavior if she had been exposed to the comparison. In Experiment 2, all participants were exposed to signaled and unsignaled delay fading in the context of a reversal design. Results for 2 of 3 participants showed that responding persisted at lengthier reinforcement delay values when signals were used. These results suggested that, for 2 participants, (a) interaction effects influenced responding in Experiment 1, and that (b) the presence of signals facilitated response maintenance during delayed reinforcement.

Introduction

Identification of the function of behavior is the hallmark of applied behavior analysis for the assessment and treatment of problem behavior for individuals with developmental disabilities. The conceptual and empirical development of learning theory, as applied to behavior disorders, has advanced the assessment and treatment of problem behavior from reliance on default technologies to a science of studying behavior-environment interactions. Skinner (1953) stated that behavior should be studied as a subject matter of its own. For applied behavior analysis, Skinner's intensive, long-term study of individual subjects' behavior-environment interactions evolved from the examination of simple and complex reinforcement schedules to the theoretical analysis of self-injurious behavior (SIB; Carr, 1977), the development of research methods dedicated to the analysis of socially important behavior problems (Bijou, Peterson, & Ault, 1968; Thomas, Becker, & Armstrong, 1968), and the birth of applied behavior analysis as a science of its own, both conceptually (Baer, Wolf, & Risley, 1968) and empirically (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994).

The study of contingencies of reinforcement (and thus functional analysis) is based on the presumption that behavior is learned through behavior-environment interactions (Baer, Wolf, & Risley, 1968; Bijou & Baer, 1961; Mace, 1994; Skinner, 1953). Baer, Wolf, and Risley defined applied behavior analysis along 7 dimensions: applied, behavioral, analytic, technological, conceptual systems, effective, and generality; these foundations of applied behavior analysis led to the development of the functional analysis methodology, which Mace (1994, p. 285) described as the "first comprehensive and standardized functional analysis methodology." Functional analysis in general, and the functional analysis methodology described by Iwata et al. (1982/1994) in particular, captures the nature of the study of behavior-environment interactions and the science of behavior described by Baer, Wolf, and Risley. Mace discussed ways in which the development of functional analysis technology has affected the science of applied behavior analysis and fundamentally changed the manner in which problem behavior is assessed and treated. Treatment of behavior disorders used to rely on default technologies (e.g., overriding existing but unidentified behavior-environment interactions with potent, nonfunctional reinforcement and punishment contingencies). As an assessment tool, functional analysis methodology has provided the means to link behavior-environment interactions and treatment development, thus improving clinical outcomes and contributing to the advancement of the science of behavior.

<u>Assessment</u>

Functional analysis (Iwata et al., 1982/1994) involves exposing problem behavior to different environmental manipulations to demonstrate the specific contingencies of reinforcement contributing to the maintenance of behavior. Many studies have been conducted that have repeatedly demonstrated its effectiveness for identifying the variables that maintained problem behavior and its contribution to treatment selection. Iwata et al. (1994) conducted an experimental-epidemiological analysis of the functions of SIB in which the outcomes of treatment were grouped according to intervention and behavioral function. Assessment and treatment data were available for 121 of the 152 participants. The number of positive outcomes of a given treatment was expressed as a proportion of the applications of that treatment, and results showed unequivocally that treatment efficacy was dependent on matching treatment to the function of SIB.

The generality of functional analysis methodology has been demonstrated by extending beyond the original assessment of SIB to many other behaviors, such as aggression (Thompson, Fisher, Piazza, & Kuhn, 1998; Wacker et al., 1990), destructive behavior (Fisher, Kuhn, & Thompson, 1998), bizarre speech (Mace & Lalli, 1991), stereotypy (Kennedy, Meyer, Knowles, & Shukla, 2000; Lerman, Iwata, Zarcone, & Ringdahl, 1994), pica (Piazza, et al., 1998; Piazza, Hanley, & Fisher, 1996), and tantrums (Carr & Durand, 1985). Furthermore, some studies have shown that treatments based on the hypothesized function of problem behavior were more effective than those selected arbitrarily (e.g., Day, Rea, Schussler, Larsen, & Johnson, 1988; Repp, Felce, & Barton, 1988). Finally, Vollmer and Iwata (1992) reported that differential reinforcement procedures (which are among the most common treatments for problem behavior) were more likely to be effective when treatment was based on the results of a functional analysis.

The effectiveness of this technology for identifying the function of problem behavior and contributing to treatment selection has stimulated extensions of functional analysis methodology to improve its practicality, efficacy, and generality. For example, Northup et al. (1991) conducted brief (i.e., 90 min) functional analysis assessments for 3 individuals. The participants were exposed to each functional analysis condition for 10 min.

A contingency reversal was then conducted in the condition that produced the highest levels of problem behavior. That is, an alternative response was taught to replace the problem behavior. Northup et al. demonstrated that in some cases, an abridged form of functional analysis procedures may be useful for identifying the function of problem behavior and aiding treatment selection. Other evaluations of brief functional analysis procedures also suggested that in some cases, brief functional analyses may be adequate for identifying the function of problem behavior (Cooper et al., 1992; Derby et al., 1992; Harding, Wacker, Cooper, Millard, & Jensen-Kovalan, 1994; Kahng & Iwata, 1999; Wacker, et al., 1994; Watson & Sterling-Turner, 1998; Wilder, Masuda, O'Connor, & Baham, 2001).

One limitation of brief functional analyses, and a problem sometimes encountered during full-length functional analyses, is that they may produce undifferentiated results. Some data analysis methods have been developed to assist in clarifying the results of unclear functional analyses. Vollmer, Iwata, Zarcone, Smith, and Mazaleski (1993a) examined within-session patterns of responding to control for varying patterns of responding within and across functional analysis sessions. A minute-by-minute inspection of functional analysis data corresponded with responding across the entire sessions and also clarified the results of one undifferentiated functional analysis. Roane, Lerman, Kelley, and Van Camp (1999) also conducted within-session analyses of functional analysis data. Responding during functional analysis sessions was expressed as a frequency when establishing operations (EO; Michael, 2000) were present and absent. Then, response rates in the presence and absence of the putative reinforcers were compared. Results showed that the within-session analyses confirmed the results of the functional analyses for 3 participants. In addition, for 1 participant, the results of the within-session analysis suggested that SIB was multiply maintained by social reinforcement, and was not maintained by automatic reinforcement. Finally, for 1 participant, results of the within-session analysis suggested that disruption was not sensitive to social contingencies and was maintained by automatic reinforcement. The results for the final 2 participants were particularly helpful because the within-session analyses both identified the function of the problem behavior and also ruled out other potential maintaining sources of reinforcement.

An additional method for clarifying the results of undifferentiated functional analyses is manipulation of the experimental design to eliminate uncontrolled sources of variability. Vollmer, Iwata, Duncan, and Lerman (1993) conducted functional analysis conditions in a reversal design to control for possible interaction effects during the multielement functional analysis. Another similar method for controlling for interaction effects was evaluated by Iwata, Duncan, Zarcone, Lerman, and Shore (1994). Each test condition was alternated with a control condition within a reversal design, and results clarified or replicated the results of a traditional functional analysis. Finally, Vollmer, Marcus, Ringdahl, and Roane (1995) developed an experimental sequence to aid in obtaining clear and replicable functional analyses. Functional analyses sometimes yield inconclusive results because of brief observations, interactions across experimental conditions, multiple control, or other unknown factors. Vollmer et al. evaluated a 4-phase assessment sequence of functional analysis: brief, multielement, extended no interaction, and reversal design. They suggested beginning with phase 1 and sequentially exposing individuals to the experimental sequence until a clear pattern of responding emerges as a method for obtaining the clearest results in the least amount of time.

Another extension of the original functional analysis procedures has been the evaluation of idiosyncratic influences on the assessment results. Carr, Yarbrough, and Langdon (1997) manipulated the presence of idiosyncratic stimuli within sessions. Results showed that the participants' rates of aberrant behavior were correlated with the presence of the stimuli. Functional relationships during the test conditions of the functional analyses were demonstrated only when these idiosyncratic stimuli were included within the sessions. Van Camp et al. (2000) extended these results by assessing the specific influence of the components of the stimuli that were associated with increased levels of problem behavior that was maintained by automatic reinforcement. For the first participant, the results of a component analysis of a vibrating toy suggested that vibration, and not other characteristics of the toy, occasioned hand biting. For a second participant, the results of a component analysis of various aspects of the toy play condition demonstrated that time-out from either attention, toys, or both contingent on hand flapping was an effective treatment. Problem behavior was successfully treated only after the particular idiosyncratic stimuli which occasioned responding were identified. Finally, the results of some studies suggest that idiosyncratic variables such as noise (McCord, Iwata, Galensky, Ellingson, & Thompson, 2001; O'Reilly, Lacey, & Lancioni, 2000) and medical conditions such as otitis media (O'Reilly, 1997) may be critical influences on the results of functional analyses.

Another potential influence on rates of problem behavior during functional analyses may be the effects of differing levels of exposure to stimuli, which may function as inadvertent EO manipulations. Fisher, Piazza, and Chiang (1996) compared the results of functional analyses that provided unequal (e.g., brief attention vs. 30 s of escape) and equal (e.g., 20-s access to reinforcers across test conditions) exposure to reinforcer duration. Results showed that the duration of access to reinforcers affected rates of problem behavior and thus may alter interpretations of functional analysis results. Responding is more likely to occur when the EO in each test condition is present rather than absent (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993a), and equating reinforcer duration across conditions may eliminate differing levels of exposure to EOs as a potential influence on the results of functional analyses.

Despite numerous procedural variations and methods of analysis, the common objective of all functional analysis procedures and data-analysis methods is the identification of the variables that maintain behavior. In this way, treatments that are matched to the function of problem behavior (which are more likely to be effective; Iwata et al., 1994) may be implemented.

Treatment

Treatments based on the outcomes of functional analyses typically involve terminating the reinforcement contingency for problem behavior (extinction) and providing reinforcement either noncontingently or contingent on appropriate behavior.

Extinction. Extinction involves terminating the reinforcement contingency that maintains a response, producing a decrease in the occurrence of the response over time (Lerman & Iwata, 1996). Iwata, Pace, Cowdery, and Miltenberger (1994) described three procedural variations of extinction that may be used as treatment for problem behavior. Each of these variations functions to terminate a particular source of reinforcement. If problem behavior is maintained by positive reinforcement, extinction involves withholding attention or materials contingent on the occurrence of problem behavior (e.g., Day et al., 1988; Lovaas & Simmons, 1969). If problem behavior is maintained by negative reinforcement, extinction involves continuing the ongoing demand situation despite the occurrence of problem behavior (e.g., Iwata, Pace, Kalsher, Cowdery, & Caltaldo, 1990; Repp et al., 1988). If problem behavior is maintained by automatic reinforcement, discontinuation of the reinforcement contingency may be achieved by reducing or eliminating the source of stimulation. Extinction-like decreases in behavior have been obtained when problem behavior was allowed to occur and protective equipment was provided that attenuated the consequences of the response, thus disrupting the reinforcement contingency (e.g., Rincover & Devany, 1982).

Iwata, Pace, Cowdery, and Miltenberger (1994) compared and contrasted the procedural forms and functions of extinction. Functional analyses of headbanging for 3 participants suggested positive reinforcement in the form of attention, negative reinforcement in the form of escape from educational demands, and automatic reinforcement, respectively, as the variables maintaining problem behavior. Functional variations of extinction were then examined by exposing each participant to at least two extinction procedures. For the participant whose SIB was maintained by attention, sensory extinction (i.e., application of a helmet) did not decrease the behavior, whereas terminating the attention reinforcement contingency for headbanging was an effective treatment. For the participant whose headbanging was maintained by escape from demands, sensory extinction and withdrawal of attention did not decrease the occurrence of SIB, whereas the continuation of demands (escape extinction) reduced responding. For the participant whose headbanging was maintained by automatic reinforcement, neither of the social extinction treatments was effective in reducing rates of SIB, and sensory extinction produced a decrease in the behavior. These findings clarified that extinction constitutes discontinuation of a reinforcement contingency. Despite the various procedural forms that have been developed, all functional extinction procedures involve termination of the response-reinforcer relationship; termination of the reinforcer contingency is critical for successful treatment.

Noncontingent and Differential Reinforcement. Many treatments for problem behavior that are based on the results of functional analyses involve extinction implemented in conjunction with another procedure, such as noncontingent reinforcement (NCR) or differential reinforcement (differential reinforcement of other behavior [DRO] or differential reinforcement of alternative behavior [DRA]). NCR involves the delivery of the maintaining reinforcer on a time-based schedule (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993b). Although the noncontingent delivery of reinforcers has had a long history in the literature as a control procedure, NCR has recently been used as a treatment for problem behavior (e.g., Fischer, Iwata, & Mazaleski, 1997; Hagopian, Fisher, & Legacy, 1994; Hanley, Piazza, & Fisher, 1997; Mace & Lalli, 1991; Vollmer et al., 1993b). Most NCR procedures are implemented with an extinction component (Carr, Bailey, Ecott, Lucker, & Weil, 1998), and reinforcement is delivered independent of responding. Such procedures likely produce reductions in responding for 2 reasons (Lalli, Casey, & Kates, 1997). First, terminating the response-reinforcer relationship functions as extinction because reinforcement is delivered independent of responding (occurrences of the response no longer produce the reinforcer). Second, such response-independent reinforcement delivery likely functions as an abolishing operation because noncontingent access to reinforcers may decrease the motivation to engage in problem behavior to access reinforcement.

Differential reinforcement procedures, including DRO and DRA, are among the most commonly used interventions for problem behavior (Vollmer & Iwata, 1992). In DRO, the reinforcer that maintains problem behavior is provided contingent on the absence of the response for some pre-specified time interval (Vollmer & Iwata). Mazaleski, Iwata, Vollmer, Zarcone, and Smith (1993) evaluated the separate and combined effects of reinforcement and extinction for 3 participants, and showed that DRO plus extinction was effective in reducing SIB maintained by positive reinforcement. When DRO was implemented without extinction, the participants continued to engage in SIB. Low rates of SIB were obtained when extinction was implemented alone or combined with DRO. In contrast, DRA involves providing the reinforcer that maintains problem behavior contingent on some alternative response, and withholding reinforcement when problem behavior occurs. For example, Piazza, Moes, and Fisher (1996) withheld escape for destructive behavior and provided escape contingent on task compliance. The results showed that differential reinforcement of compliance (DRC), escape extinction, and demand fading decreased escape-maintained destructive behavior and increased compliance during tasks.

A potential advantage of DRA over DRO or NCR is the availability of another response to attain reinforcement. DRA may be more beneficial than DRO or NCR as a treatment for problem behavior for individuals with developmental disabilities because DRA may increase individuals' behavioral repertoires (e.g., LaVigna & Donnellan, 1986). Because individuals with developmental disabilities may have limited means of attaining appetitive stimuli (Bijou, 1966; Ferster, 1961), an increase in available responses to attain reinforcement may produce concomitant decreases in problem behavior if responding is allocated to the alternative behavior. DRO procedures do not specifically arrange for new responses to be reinforced (Poling & Ryan, 1982). Therefore, increasing the adaptive behavioral repertoire of individuals with developmental disabilities is a potential benefit of DRA.

Functional Communication Training. Functional communication training (FCT; Carr & Durand, 1985) is a specific type of DRA procedure which uses a communicative response for the alternative behavior. As discussed by Carr & Durand (1985) and Wacker et al. (1990), FCT differs from DRA in at least 2 ways. First, the participant is somewhat in control of the schedule of reinforcement in FCT. For example, reinforcement may be continuously available to the participant, but reinforcement is only delivered when it is solicited. In contrast, escape from demands is available only when demands are present and compliance occurs in a DRA procedure, thus limiting the opportunities for a response to be reinforced and strengthened. Second, FCT may arrange for a more efficient way to contact reinforcement. For example, in a DRA procedure, escape may be available contingent on a complex task, such as folding a towel. In FCT, escape may be available contingent on a verbal response, such as "break please." Although not necessarily demonstrated empirically, it is reasonable to assume that a brief verbal response may require less effort than a complex motor task and thus be more likely to occur (Horner & Day, 1991).

Like DRA, FCT generally involves terminating the reinforcement contingency for problem behavior and using the same reinforcer for acquisition and maintenance of an alternative response (Shirley, Iwata, Kahng, Mazaleski, & Lerman, 1997). Subsequent to identifying the variable(s) that maintains problem behavior via functional analysis, problem behavior is exposed to extinction and an alternative response is shaped by providing the maintaining reinforcer contingent on the response. For example, if an individual’s problem behavior was maintained by access to tangibles, tangibles would no longer be provided contingent on problem behavior and would instead be provided contingent on some alternative response (e.g., saying, “toy please”). The rationale is that individuals will be less likely to engage in problem behavior when the reinforcement contingency for the problem behavior is terminated and some other response produces the reinforcer (Shirley et al., 1997).

Many studies have demonstrated the utility of FCT for decreasing problem behavior and increasing adaptive behavior (e.g., Carr & Durand, 1985; Durand & Carr, 1991; Fisher et al., 1993). Carr and Durand (1985) first identified the function of disruptive behavior exhibited by four individuals diagnosed with developmental delays. Disruption was then placed on extinction, and reinforcement was delivered contingent on alternative responses that solicited attention or assistance. Results showed acquisition of the communicative responses and decreases in destructive behavior. FCT has been shown to be effective for treating various behavior problems (e.g., aggression and SIB; Belfiore, Browder, & Lin, 1993; Bird, Dores, Moniz, & Robinson, 1989; Jayne, Schloss, Alper, & Menscher, 1994) and has been shown to be effective across settings (Campbell & Lutzker, 1993; Hunt, Alwell, & Goetz, 1988; Smith & Coleman, 1986). FCT may also have robust, lasting effects. For example, Durand and Carr (1991) found that treatment effects were maintained for 18 to 24 months after the onset of treatment for 3 participants who were exposed to FCT. Derby et al. (1997) found that treatment effects maintained for up to 27 months and were correlated with substantial response generalization for 4 children.

Recently, some studies have examined the relative contributions of different components of FCT in the acquisition and maintenance of alternative responses (e.g., Fisher et al., 1993; Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998; Kelley, Lerman, & Van Camp, 2001; Shirley et al., 1997; Wacker et al., 1990; Worsdell, Iwata, Hanley, Thompson, & Kahng, 2000). Shirley et al. examined whether alternative responses could be acquired when both occurrences of problem behavior and of the alternative response produced reinforcement on continuous schedules. Extinction for problem behavior was necessary to attain acquisition of the alternative responses. On the other hand, Kelley et al. and Worsdell et al. examined whether alternative responses could be acquired when both occurrences of problem behavior and the alternative response produced reinforcement on intermittent schedules. The results of Kelley et al. showed that extinction for problem behavior was necessary for acquisition of an alternative response for 2 of 3 participants. The results of Worsdell et al. suggested that acquisition of alternative responses may be possible when problem behavior continues to contact reinforcement on relatively thin schedules.

Although few studies have examined the conditions under which acquisition of alternative responses may be acquired, several studies have examined the necessary components of FCT treatments after acquisition of an alternative response. Wacker et al. (1990) studied the separate and combined effects of extinction, time-out, and graduated guidance during FCT. Results showed that acquisition of alternative responses and reductions in problem behavior were achieved when problem behavior was exposed to extinction during FCT. However, these treatment effects were not maintained when reinforcement for problem behavior was reintroduced. They concluded that extinction for problem behavior was necessary to maintain both occurrences of an alternative behavior and low rates of problem behavior. Fisher et al. (1993) examined the extent to which extinction and punishment for problem behavior were necessary to attain and maintain treatment success. Results showed that FCT alone (e.g., without extinction) was successful in reducing problem behavior for just one of four participants, and that extinction was necessary to decrease problem behavior for the other three participants. Hagopian et al. (1998) also examined the effects of FCT with and without extinction and punishment. Results showed that FCT without extinction generally was ineffective in reducing problem behavior and increasing an alternative response and FCT with extinction was effective in reducing problem behavior for all participants.

Although DRA and FCT procedures have been shown to be effective for decreasing problem behavior and producing acquisition and maintenance of alternative responses, both treatments have limitations. DRA and FCT treatments often incorporate rich schedules of reinforcement. Although these treatments may be successful for decreasing problem behavior and maintaining appropriate behavior, treatments that contain rich schedules of immediate reinforcement may be problematic for several reasons (Hanley, Iwata, & Thompson, 2001). First, there are times when it may be impossible, impractical, or inconvenient to deliver a stimulus immediately following the occurrence of a behavior. Delivering reinforcement immediately after the occurrence of a response may disrupt normal social activities for the person responsible for delivering reinforcement (e.g., when a parent is talking on the telephone) or may disrupt ongoing academic activities (e.g., when a teacher is providing academic instruction in a classroom). Second, there are times when a particular stimulus may not be available. For example, an individual may request access to a certain food item that requires preparation, thereby delaying access to the reinforcer. Finally, many FCT treatments use continuous or near-continuous schedules of reinforcement to maintain a strong response-reinforcer relationship. However, this type of schedule arrangement often leads to high reinforcement rates (Hanley et al., 2001). High reinforcement rates may be problematic for some of the reasons listed above (i.e., it may be inconvenient or impractical to deliver reinforcement at a particular time). High reinforcement rates may also pose other problems such as health concerns if an individual is engaging in a response to contact food reinforcement.

Delayed Reinforcement

One potential strategy for attenuating the limitations of typical FCT treatments may be to establish conditions under which a response will maintain despite the delayed delivery of its consequences. Introducing delays between a response and its maintaining consequence may increase the generality of treatment. Differential reinforcement treatments that include a delay to reinforcement may be more practical and easier to use than treatments in which reinforcement must be delivered immediately. However, results of both basic and applied studies suggest that delaying the delivery of a consequence that maintains a response may have contingency-weakening effects (Hanley et al., 2001; Lattal, 1974). If the response-reinforcer relationship is disrupted when delays to reinforcement are introduced, it is likely that treatment will be less effective.

Some applied research has investigated the extent to which delays to reinforcement may be implemented during response maintenance. Hanley et al. (2001) evaluated methods for thinning reinforcement schedules during treatment with FCT. For one participant, the delay to reinforcement was systematically increased for a response that was maintained on an FR-1 schedule. Consistent with results of both basic and applied research (e.g., Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Schaal & Branch, 1988), the participant initially continued to engage in stable rates of responding; however, responding eventually decreased to zero when the delay reached 16 s and 25 s. These data suggested that the response-reinforcer relationship degraded sufficiently to produce effects similar to those of extinction as the delay was increased.

Fisher et al. (2000) investigated conditions under which tolerance for delays to reinforcement could be established during treatment with FCT. For one participant, reinforcer delay fading alone was sufficient to maintain rates of the alternative response. The interval between the response and reinforcer delivery was gradually lengthened from 0 s to 30 s. Results showed that the participant continued to engage in the alternative response and rates of problem behavior remained low despite the introduction of delayed reinforcement. For 2 participants, additional interventions (i.e., punishing problem behavior, providing tasks to complete during the delay interval) were necessary to maintain treatment effects during fading.

Other studies have evaluated the effects of introducing tasks during the delay to reinforcement (e.g., Binder, Dixon, & Ghezzi, 2000; Dixon & Halcomb, 2000). Dixon and Cummings (2001) evaluated the effects of a response requirement (a task-related activity) on choice behavior during a delay period. Results showed that participants preferred to engage in an activity rather than simply to wait during delays to reinforcement. Participants also engaged in lower levels of problem behavior when tasks were available during the delay interval. Although these activities were not specifically programmed to function as signals during the delay period, Fisher et al. (2000) suggested that such activities may function as discriminative stimuli that signal the subsequent delivery of reinforcement. However, these studies (e.g., Dixon & Cummings; Fisher et al.) did not specifically evaluate the mechanisms by which these activities facilitated responding during reinforcement delay fading.

Hagopian et al. (1998) conducted a large-scale (N=21), single-subject study on the effectiveness of FCT with and without extinction and punishment in which delay-to-reinforcement fading was conducted with participants for whom occurrences of a communicative response were maintained by positive reinforcement in the form of access to attention or tangibles (8 of the 21 participants). Delay-to-reinforcement fading began with a 1-s to 3-s delay between the response and reinforcement delivery. Subsequent fading steps were made in small increments (i.e., 1 s, 3 s, 5 s, 7 s, etc.). The authors reported that this procedure resulted in a 90% reduction in baseline rates of problem behavior for 4 of 8 participants. In addition, the authors reported means of the communication response for one sample case that suggested that the behavior maintained despite the introduction of delayed reinforcement (the average delay-to-reinforcement time across participants was 3.2 min). However, the response occurred at lower rates during delayed reinforcement relative to when reinforcement was delivered immediately following the occurrence of the response. Therefore, Hagopian et al. were able to maintain treatment effects and decrease the effort associated with treatment implementation via large delays to reinforcement.

Results of some applied studies also show how delays to reinforcement may influence responding under concurrent-operant arrangements (Neef, Mace, & Shade, 1993; Neef, Shade, & Miller, 1994). For example, Neef et al. (1993) demonstrated that students allocated responding in a manner consistent with the matching law (Herrnstein, 1961; 1970) when delays to reinforcement were equal across response alternatives (i.e., responding was allocated in proportion to the relative rates of reinforcement when delays were equal across response alternatives). When delays to reinforcement differed across response alternatives, one student allocated responding to the alternative that produced immediate reinforcement. The other student responded to the alternative associated with greater rate and quality of reinforcement despite the introduction of a delay to reinforcement. Although the effects of delayed reinforcement were idiosyncratic across participants, results suggested that introducing delays to reinforcement for one response may influence response allocation when immediate reinforcement is available for an alternative response. Thus, a delayed reinforcer may not be effective for maintaining a behavior (e.g., a communication response) if reinforcement is immediately available for another response (e.g., problem behavior). However, the results also suggested that manipulating other reinforcement parameters such as quality or magnitude may be an effective strategy for increasing the effectiveness of delayed reinforcement.

Although these studies have begun to evaluate conditions under which responding may maintain despite delays to reinforcement, the specific conditions under which response maintenance may be achieved when reinforcer deliveries are delayed have not been thoroughly and systematically assessed in applied research. For example, as discussed in the next section, stimuli presented during delays to reinforcement have been shown to help maintain responding relative to conditions in which no stimuli are provided.

Basic Research on Delayed Reinforcement

Much basic research has employed auditory and visual stimuli, often to signal some change in reinforcement conditions. Such signals eventually exert some control over behavior due to the correlation between the stimulus and a specific reinforcement schedule. Signals have been used in many schedule arrangements (e.g., Belke & Spetch, 1994; Lattal, 1984; Schaal & Branch, 1988; Schaal & Branch, 1990). Some studies have used stimuli simply to signal a change in a reinforcement contingency, such as the completion of an initial-link schedule and the initiation of a terminal-link schedule in chain-schedule procedures (e.g., Belke & Spetch, 1994; Dunn & Spetch, 1990; McDevitt, Spectch, & Dunn, 1997; Spetch, Belke, Barnet, Dunn, & Pierce, 1990). Other studies have used signal manipulations as the principal independent variable under investigation (e.g., Lattal, 1984; Marcattilio & Richards, 1981; Richards, 1981; Schaal & Branch, 1988; Schaal & Branch, 1990).

The effects of signals on responding have been evaluated with nonhumans by arranging a condition in which an organism has the opportunity to choose between schedules containing either signaled or unsignaled reinforcement delivery (e.g., Badia, Ryan, & Harsh, 1981). Alternatively, in some studies, organisms could respond to arrange or maintain conditions under which reinforcement delivery was signaled or unsignaled (e.g., Lewis, Lewin, Muehleisen, & Stoyak, 1974). In general, results suggest that organisms will choose signaled reinforcement over unsignaled reinforcement and will respond to arrange or maintain conditions in which reinforcement is signaled. Various explanations have been offered to explain preference for signaled reinforcement. In particular, some authors have suggested that the signals per se function as conditioned reinforcers due to the pairing of the stimulus with reinforcement delivery (Belke & Spetch, 1990; Harsh, Badia, & Ryan, 1983; Harsh, Badia, & Ryan, 1984).

One area of basic research on signal manipulations that has received some attention is responding under conditions of delayed reinforcement. Typically, the purposes of such studies are to determine (a) the conditions under which baseline rates of responding will maintain when delays to reinforcement are introduced, and (b) the extent to which delays to reinforcement can be increased while maintaining responding. Results of some studies have shown that the presentation of signals during delays to reinforcement may attenuate extinction-like decreases in responding (e.g., Lattal, 1984; Schaal & Branch, 1988).

For example, Schaal and Branch (1988) compared response rates under conditions of unsignaled, briefly-signaled, and completely-signaled delays to reinforcement.

In Experiment 1, the authors established pigeons' key pecking on a VI-60 schedule. They then introduced a 1-s delay to reinforcement, which decreased response rates relative to baseline with immediate reinforcement. Response rates returned to baseline levels when a signal (i.e., a change in the color of the key light) was introduced during the first 0.5 s of the delay (i.e., the signal occurred immediately after the first response that satisfied the schedule requirement). Baseline response rates were maintained with this brief signal at 1-s, 3-s, and 9-s delays to reinforcement, but not with 27-s delays.

In Experiment 2, the authors arranged multiple (MULT) VI-60 VI-60 schedules in baseline with immediate reinforcement and introduced a 3-s delay in each component, which resulted in decreased response rates relative to baseline. A brief signal then was used in one component and a complete signal in the second component (i.e., the signal lasted just 0.5 s in the first component and the entire delay in the other component). Responding increased to and remained at baseline levels in both components under both a 3-s delay and a 9-s delay (as in the first experiment). However, responding remained at baseline levels only in the completely-signaled component when the delay was increased to 27 s. These results extended those of Experiment 1 by demonstrating that baseline response rates under immediate reinforcement were maintained under a completely-signaled 27-s delay to reinforcement.

Schaal and Branch (1990) evaluated the effects of the duration of a signal on pigeons' key pecking during a delay to reinforcement. In Experiment 1, the authors used a multiple-schedule arrangement in which a 27-s delay to reinforcement followed the first response that satisfied a MULT variable interval (VI) 60-s VI 60-s reinforcement schedule. In the first component of the multiple schedule, a 0.5-s signal immediately followed the first response that satisfied the schedule requirement; the signal duration was then systematically increased during the 27-s delay across phases. In the second component of the multiple schedule, the signal was present during the entire 27-s delay period; the signal duration was then systematically decreased during the delay. Response rates were positively correlated with the signal length duration in both components. However, when the signal lengths were equal across the two conditions, response rates were higher in the condition in which the signal had been decreased than in the condition in which the signal duration had been increased.

In Experiment 2, responding produced reinforcement on a VI-60 schedule with a 27-s delay. The authors increased the signal duration in the same manner as in the first experiment (starting with a 0.5-s signal). The results replicated those of the first experiment in that as the signal duration increased to the entire 27-s delay, response rates also increased. Furthermore, when shorter delay signals were "abruptly" introduced (i.e., the signal duration was not gradually increased as in Experiment 1), response rates observed during the second exposure to the abruptly introduced, shorter signals were higher than those observed under the increasing signal duration condition at the same signal length (i.e., replicating the results of Experiment 1).

To summarize, the results of these experiments showed that (a) response rates were positively correlated with the signal duration during a 27-s delay to reinforcement, and (b) response rates tended to be higher (at equal signal durations) when the signal duration had been gradually decreased from the 27-s signal duration or when a shorter signal duration had been abruptly introduced. Similar to the Schaal and Branch (1988; 1990) experiments, Lattal (1984) showed that providing signals under conditions of delayed reinforcement attenuated decreases in rates of pigeons' key pecking. Response rates were positively correlated with the percentage of trials containing signals, suggesting that the presence of the signals influenced responding.

Results of these studies generally suggest that providing signals during a delay to reinforcement may attenuate decreases in response rates. Results of Schaal and Branch (1988; 1990) showed that responding may decrease under conditions of unsignaled, delayed reinforcement relative to baseline with immediate reinforcement. However, providing brief signals at the completion of a reinforcement contingency (thus signaling that a reinforcer delivery was imminent) attenuated decreases in responding at 3-s and 9-s delays to reinforcement. Furthermore, responding under delay values as long as 27 s was similar to responding under immediate reinforcement when a signal was provided for the entire delay.

These findings may have important clinical implications. As described previously, arranging conditions in which responding may maintain despite the use of delayed consequences may be beneficial for treatments for individuals with disabilities (see Stromer, McComas, & Rehfeldt, 2000, for a discussion of this issue). Few applied studies have introduced delayed reinforcement within treatment packages, and those that have generally showed minimal success (e.g., Hagopian et al., 1998). Results of basic research on signaled, delayed reinforcement may have practical applications for both treating severe behavior problems and for identifying conditions under which behavior may maintain when responding contacts delayed consequences.

Applied Research on Signaled Reinforcement

Although signaled delays have been studied extensively in the basic literature, signals during delays to reinforcement have rarely been evaluated in the applied literature. In one exception, Vollmer, Borrero, Lalli, and Daniel (1999) evaluated response allocation under signaled and unsignaled delay-to-reinforcement conditions. In the fourth and final phase of their study, the authors tested for "impulsive responding" during signaled and unsignaled reinforcement delays. Occurrences of problem behavior produced a small, immediate reinforcer and occurrences of the alternative response produced a large, delayed reinforcer. Both participants allocated responding to the alternative response (i.e., the response that produced the larger, delayed reinforcer) on a high percentage of trials when the delays were signaled. Conversely, responding was allocated to problem behavior (i.e., the response that produced the small, immediate reinforcer) on a high percentage of trials when the delays were unsignaled. These results suggested that in a concurrent-operants procedure, even a small (i.e., 10-s) delay to reinforcement may disrupt responding such that individuals may forego a larger, delayed reinforcer in favor of a smaller, immediate reinforcer (i.e., engage in impulsive responding). Moreover, individuals may more easily tolerate delays to reinforcement (i.e., engage in self-control behavior) when signals are used.

To summarize, very little applied research has focused on specific conditions under which responding may maintain when reinforcement is delayed. Some applied research has examined conditions under which unsignaled delays to reinforcement may be established (e.g., delay fading; Fisher et al., 2000; Hanley et al., 2001) and how signals may influence impulsive and self-control responding in a concurrent-operants format (Vollmer et al., 1999). Results of basic research on signaled and unsignaled delays to reinforcement suggest that under some conditions (i.e., providing signals), responding may maintain when reinforcement is delayed (Schaal & Branch, 1988; Schaal & Branch, 1990). However, these conditions have not been specifically examined in applied research.

Determining the conditions and the extent to which responding may be maintained under delayed reinforcement has several important applied implications. It can often be difficult or impossible to deliver certain reinforcers immediately following the occurrence of a response. For example, an individual may request an item during academic instruction that is only available during recess. As stated before, many treatment procedures, especially FCT treatments, involve the immediate delivery of a reinforcer on a continuous or rich intermittent reinforcement schedule (Hanley et al., 2001). Dense reinforcement schedules may not be in the overall best interests of individuals with developmental disabilities. For example, if an individual engages in high rates of a response that produces tangible reinforcement, he or she may engage in that response to the exclusion of other responses, thus competing and interfering with other habilitative services such as education or skill training. Establishing a reinforcement schedule that maintains a strong response-reinforcer relationship (e.g., FR 1 or a rich intermittent schedule) despite a delay in reinforcement may have several beneficial effects. First, reinforcement is delivered following every occurrence of the response, thus preventing ratio strain that may occur under thin reinforcement schedules. Second, delaying reinforcement may increase the time available for educational activities. Third, delayed reinforcement may prevent reinforcer satiation, which may occur with more frequent access to reinforcement. Finally, treatment with delayed reinforcement may be easier to implement with a high degree of integrity than a treatment that requires more frequent reinforcer deliveries. Discovering the conditions under which delayed reinforcement is effective may improve the quality of treatments involving FCT and DRA.

Purpose

FCT has been shown to be an effective treatment for producing acquisition of socially acceptable responses (e.g., Carr & Durand, 1985; Fisher et al., 1993; Shirley et al., 1997; Wacker et al., 1990). This treatment is designed to provide individuals with developmental disabilities with a repertoire of responses to attain reinforcement. If socially acceptable responses are not specifically shaped and maintained in the natural environment, individuals may contact extended periods of deprivation of preferred stimuli or may develop behavioral repertoires that include maladaptive responses. Therefore, it is important to develop technologies for ensuring that adaptive behavior persists despite treatment challenges such as intermittent reinforcement schedules, periods of extinction, and delayed reinforcement.

One potential avenue of research that has not been well studied in the applied literature is the effect of signals on responding when reinforcement delivery is temporally delayed relative to the occurrence of a functional response. Results of several applied studies have shown that responding generally decreases when delays to reinforcement are introduced (Fisher et al., 2000; Hagopian et al., 1998; Hanley et al., 2001). Results of basic research have shown that the presence of signals during delays to reinforcement attenuates decreases in responding that occur when reinforcement delays are not signaled (e.g., Schaal & Branch, 1988; Schaal & Branch, 1990). Three applied studies have begun to examine the variables that may influence responding when reinforcement is delayed. Results of Fisher et al. and Hagopian et al. showed that slowly increasing the delay time between a response and reinforcement delivery in a single-operant format produced moderate success in maintaining responding despite delayed reinforcement. Vollmer et al. (1999) extended this line of research by evaluating relatively large delays to signaled reinforcement in a concurrent-operants format. Responding during delayed reinforcement has been studied systematically in the basic literature (e.g., in single and concurrent-operant formats; with various reinforcement schedules). More systematic applied research is needed to discover specific conditions under which responding may maintain despite delayed reinforcement.

The purpose of the current study was to evaluate the extent to which signals may influence responding when the delays to reinforcement are gradually increased over time. Basic research has demonstrated that presenting signals during delayed reinforcement has been effective at maintaining responding at higher rates and longer delay intervals than conditions in which delayed reinforcement is not signaled. Experiment 1 evaluated the extent to which these findings may operate in applied situations with human participants in the context of a multielement design. In Experiment 2, a reversal design was used to examine (a) the degree to which signals influenced responding when the delay to reinforcement was gradually increased over time, and (b) the hypothesis that interaction effects were responsible for the negative effects obtained in Experiment 1.

General Method

Participants and Settings

Participants were 3 individuals diagnosed with developmental disabilities who were referred to a facility that specializes in the assessment and treatment of severe behavior disorders. All participants were referred for assessment and treatment of problem behavior and were in various stages of assessment and/or treatment at the time of this study. None of the treatments implemented with the participants outside of the experimental sessions prior to or during the course of this study were similar to those used in the study. Problem behavior was not specifically addressed in the study. These individuals were selected because (a) communication training was identified as a treatment goal by their therapy teams, and (b) they were available to participate in daily experimental sessions.

Brian was a 14-year-old boy diagnosed with severe mental retardation and autism. Brian was nonverbal and did not consistently follow verbal requests. He was originally referred for assessment and treatment of several topographies of problem behavior, including self-injury and aggression. His individual education plan (IEP) goals included increasing communication and better tolerating delays to reinforcement. Caregivers reported that Brian was likely to engage in self-injury and aggression when access to preferred stimuli was delayed or denied. However, a functional analysis conducted prior to this study did not identify a clear function for these behaviors.

Chuck was an 8-year-old boy diagnosed with severe mental retardation, cerebral palsy, and autism. Chuck sometimes followed one-step directions, was nonverbal, and communicated mainly by way of gestures (e.g., pointing). He was originally referred for assessment and treatment of several topographies of problem behavior, including self-injury, aggression, elopement, and stereotypic behavior. Results of a functional analysis indicated that elopement was sensitive to positive reinforcement in the form of access to tangibles (specifically, access to videos on a television). No treatments relevant to this function were being implemented at the time of this study. A clear functional analysis was not obtained for any other problem behaviors.

Michele was an 8-year-old girl diagnosed with moderate mental retardation, cerebral palsy, and autism. Michele spoke in four- to six-word sentences and sometimes followed one- or two-step directions. She was referred for assessment and treatment of destructive behavior, which included aggression and property destruction. Results of a functional analysis indicated that these behaviors were maintained by negative reinforcement in the form of escape from demands. No treatments for escape-maintained behavior were in place at the time of this study.

Settings included classrooms and therapy rooms that contained tables, desks, chairs, and relevant session materials (see specific session descriptions). Brian’s sessions were conducted in a classroom that measured 6.1 m x 9.2 m. He was seated at a table facing a wall. Other students, teachers, and therapists were periodically present in the classroom but did not interact with Brian or the therapists. Chuck’s sessions were conducted in a therapy room that measured 3.1 m x 6.1 m. Only Chuck and a therapist were present in the therapy room during sessions. Observers collected data behind a one-way window. Michele’s sessions were conducted in a therapy room that measured 2.5 m x 3.1 m. Michele, the therapist, and all data collectors were present in the therapy room during sessions.

<u>Response Measurement and Reliability</u>

Target communicative responses were determined for each participant individually. All communicative responses were restricted operants so that the reinforcement schedule could be held constant despite changes to the reinforcement delay (i.e., this ensured that the target behavior could not occur during the delay). Consideration was given to each individual's communication goals and caregiver preference. Brian's target communication response was a card touch, which was defined as contact between any part of the palm-side of Brian's hand and a "snack please" card (15 cm x 20 cm), which was located 45 cm in front of him on a table. This response was selected because Brian was being taught to use a picture exchange system to guide activities of daily living at school and at home. For example, therapists prompted him to exchange a "bathroom" card (picture of a toilet) prior to using the bathroom. However, Brian did not engage in any communicative responses to access food at the time of the study. Chuck's communication response was handing a remote control to a therapist, which was defined as picking up a remote control, walking to the therapist, and placing the remote control into the therapist's hand. The television/videocassette recorder (VCR), the table on which the remote control was located, and the therapist were always in the same locations in the therapy room. The therapist sat next to the television/VCR, and the table with the remote control was approximately 3 m from the therapist. Michele's communication response was a card exchange, which was defined as picking up a "break please" card (15 cm x 20 cm) and placing it into the therapist's hand. Michele's team of therapists decided that a card exchange would be a reasonable response to use in the classroom subsequent to discharge from the program.

A graduated prompting sequence similar to that described by Shirley et al. (1997) was used to teach the communication response to each participant prior to the study. During these training trials, the therapist used a 3-step prompting sequence (i.e., successive verbal, model, and physical prompts) if the participant did not engage in the response within 5 s of the beginning of the session or the end of a reinforcement interval. Training was terminated when the participant responded independently on at least 80% of trials.

Frequency data on target behaviors were collected on laptop computers by previously trained post-baccalaureate therapists and graduate students. Data from each session were expressed as responses per minute (rpm) by dividing the total number of responses by the session time. For sessions during which a delay to reinforcement occurred, session time was adjusted by subtracting the delay intervals from the total session time prior to calculating responses per minute. As noted above, the participants did not have an opportunity to engage in the communication response during the delay interval. Omitting the delay intervals from the total session time ensured that changes in the delay to reinforcement across sessions would not influence the overall response rates.

Interobserver agreement was assessed by having a second observer simultaneously but independently collect data during 50.5%, 33.8%, and 62.5% of sessions in Experiment 1 and 28.7%, 46.4%, and 45.9% of sessions in Experiment 2 for Brian, Chuck, and Michele, respectively. Interobserver agreement for the dependent variable was calculated by dividing each session into consecutive 10-s bins and comparing the number of responses recorded in each interval by each observer. An exact agreement was defined as both observers recording the same number of responses in a given 10-s interval. The number of 10-s intervals with exact agreement was divided by the number of 10-s intervals with agreement plus disagreement, and this quotient was multiplied by 100%. Mean exact agreement for communication responses in Experiment 1 was 94.1% (range, 64.3% to 100%) for Brian, 95.7% (range, 65.0% to 100%) for Chuck, and 93.7% (range, 70.5% to 100%) for Michele. Mean exact agreement for communication responses in Experiment 2 was

96.8% (range, 87.1% to 100%) for Brian, 92.0% (range, 77.2% to 100%) for Chuck, and 96.9% (range, 81.7% to 100%) for Michele.

Experiment 1: Unsignaled Versus Signaled Delays To Reinforcement within a Multielement Design

The purpose of Experiment 1 was to determine whether a signaled delay-to-reinforcement condition would maintain responding at higher levels and longer delay intervals than an unsignaled-delay condition when delays to reinforcement were gradually lengthened. All participants except Michele were exposed to four conditions: baseline, unsignaled delay-to-reinforcement fading, signaled delay-to-reinforcement fading, and extinction (see further description below). Michele was exposed to just baseline and extinction. Two to eight 10-min sessions were conducted 2 to 5 days per week. Under the delayed reinforcement conditions, session length was increased to 15 min if the delay reached 120 s and to 20 min if the delay reached 450 s so that the participant's behavior would have more opportunities to come into contact with the contingencies. (The participants had fewer opportunities to respond within each session as the delay interval increased.).

The target terminal reinforcement delay was based on caregiver/teacher preference and was 300 s (5 min) for both Brian and Chuck. Michele was not exposed to delayed reinforcement in Experiment 1 (see further discussion below). The actual terminal delay was shorter or longer than 5 min in some phases of the study, depending on the participant's response patterns under delay fading. The delay fade was terminated before reaching 5 min if responding decreased and remained below previous levels of responding in that phase for several consecutive sessions. In addition, the terminal delay value was lengthened in some phases if responding maintained under the 5-min delay but was undifferentiated across conditions.

The reinforcers were chosen for each participant on an individual basis. Brian received noncontingent access to food throughout the day and had not been taught to engage in any communication responses to request food (a highly preferred item) at the time of the study. The specific snacks used in this study (popcorn and gummi bears) were not available to Brian at any time outside of the sessions. Chuck often attempted to operate televisions and remote controls when he came into contact with them, and watching videos had been identified as a preferred activity prior to the study. The specific video used in the study was not available to Chuck outside of sessions. Escape from demands was selected as the reinforcer for Michele because results of a functional analysis indicated that her problem behavior was functionally related to escape from demands.

Brian and Chuck were given brief access to the reinforcer prior to each session. The reinforcer then was restricted and provided for 20 s contingent on each communication response (i.e., on a continuous schedule of reinforcement [CRF]) in all conditions except extinction. For Michele, continuous demand trials involving a towel-folding task were presented using a 3-step prompting sequence (i.e., verbal, model, and physical prompts) in all conditions. A 20-s escape from the demand trials was provided contingent on each communication response in all conditions except extinction.

Baseline (Immediate Reinforcement)

All participants were exposed to this condition. Access to food (Brian), the video (Chuck), or escape from demands (Michele) was available contingent on the emission of the relevant communicative behavior. All problem behavior was ignored. Reinforcement was delivered immediately following each occurrence of the target communicative response (i.e., the delay to reinforcement was 0 s). The participant did not have the opportunity to exhibit the response while the reinforcer was available (20-s access to food, video, or escape) because the therapist retained the communication card or remote control during this time. Brian's therapist removed the card and placed it onto the seat of a chair that was under the table. Chuck's therapist placed the remote control on her lap underneath her hands. Michele's therapist removed the card and placed it onto the table behind a pile of towels.

Unsignaled Delay-to-Reinforcement Fading

Only Brian and Chuck participated in this condition. The delay to reinforcement delivery was increased by some time interval every 2 sessions. The first two delays were 2 s and 5 s. For each subsequent fading step, the reinforcement delay was increased by 30% (rounded up to the nearest whole number) of the previous delay. When the delay reached 40 s, the reinforcement delay was increased by a fixed amount of time. Table 1 shows the fading schedule for each participant. (The highest delay value reached in any phase of the experiment is shown in the table). Delay fading was continued until either (a) the target terminal delay value was reached, or (b) responding decreased and remained below previous levels of responding in that phase for several consecutive sessions. (In later phases of the study, participants were abruptly exposed to large delays if responding maintained under both signaled and unsignaled delay conditions; see results below for further discussion). Contingent on each occurrence of the

Table 1

Fading Progression in Seconds
(Highest Delay Value Reached for Each Participant)

Experiment 1		Experiment 2		
Brian	Chuck	Brian	Chuck	Michele
2	2	2	20	2
5	5	5	40	5
7	7	7	60	7
9	11	9	80	9
11	14	11	100	11
14	19	19	120	14
19	24	24		19
24	31	31		24
31	40	40		31
40	50	60		40
60	60	75		60
90	75	90		90
120	90	120		120
300	105	300		300
450	120			
600	300			
	450			
	600			
	720			

communicative response, the therapist simply waited the specified time period before delivering the reinforcer. The participant did not have the opportunity to exhibit the response during the delay interval or while the reinforcer was available (20-s access to food or video) because the therapist retained the communication card or remote control as described above.

Signaled Delay-to-Reinforcement Fading

Only Brian and Chuck participated in this condition. Procedures were identical to those in the unsignaled condition except a signal was provided during the entire delay period. Contingent on each occurrence of the communication response, the therapist presented the signal during the specified delay interval and removed it when the reinforcer was delivered. The signal used for each participant was chosen on an individual basis. Consideration was given to each individual’s sensory-motor skills (e.g., visual impairment would have precluded the use of a visual stimulus as the signal) and parental/caregiver preference (i.e., parents/caregivers were given the opportunity to aid in the selection of the signal). For Brian, the signal stimulus consisted of a closed container that contained coins. Contingent on a card touch response, the therapist placed the container in front of Brian and shook it for the duration of the delay interval so that the signal potentially provided both auditory and visual stimulation. At the end of the delay interval, the therapist removed the container and delivered 20-s access to preferred food. For Chuck, the signal consisted of the therapist holding the videotape halfway in the VCR for the duration of the delay interval. At the end of the delay interval, the therapist placed the video into the VCR and provided 20-s access to the video. The participant did not have the opportunity to exhibit the response during the delay interval or while the reinforcer was available (20-s access to food or video) because the therapist retained the communication card or remote control as described above.

Extinction

All participants were exposed to this condition. In the extinction condition, the reinforcement contingency for the communication response was terminated (i.e., no programmed consequences were provided for the response). The participant could not engage in the response for 20 s following each emission of the response (the communication card or remote control was removed). This procedure ensured that response rates would be comparable across baseline (reinforcement) and extinction conditions. As described under "baseline" above, the participant did not have the opportunity to exhibit the response while the reinforcer was available (20-s access to snacks, video, or escape).

Experimental Design

The effects of signals on responding during delays to reinforcement were assessed using a multielement design for Brian and Chuck. The two reinforcement delay conditions (signaled and unsignaled) were compared after the participants were exposed to a series of baseline (immediate reinforcement) sessions. However, other elements of the design differed for these two participants. A series of extinction sessions was alternated with the reinforcement delay conditions in a reversal design for Brian. (Extinction was implemented because responding maintained across the delayed reinforcement conditions.) Extinction and reinforcement sessions were alternated in a multielement design across all phases of the study for Chuck. In addition, a series of baseline sessions was alternated with the reinforcement delay conditions in a reversal design for Chuck. (Baseline was implemented because responding extinguished under the delayed reinforcement conditions.) Michele was exposed to baseline and extinction sessions in a multielement design. A series of extinction sessions also was conducted with Michele following the multielement comparison (see results for further discussion). During the multielement comparison phases, the order of the conditions (signaled and unsignaled for Brian; signaled, unsignaled, and extinction for Chuck; baseline and extinction for Michele) was randomized at each delay value. A different stimulus (Chuck and Michele) or therapist (Brian) was paired with each condition to facilitate discrimination between conditions that were rapidly alternated in the multielement design. The stimuli consisted of colored pieces of cardboard (55 cm x 70 cm) that were attached to the wall directly in front of the participants. Visual inspection of graphed data was used to make decisions for terminating phases.

Results and Discussion – Brian

Results for Brian are depicted in Figure 1. In the baseline (immediate reinforcement) phase, Brian engaged in stable rates of communicative behavior (*M* = 2.6 rpm). Beginning with session 11, Brian's card touching was exposed to gradually increasing delays to reinforcement in both the signaled and the unsignaled delay-fading conditions. Rates of card touching were somewhat variable but maintained at similar levels in both the unsignaled condition ($\underline{M}$ = 2.2 rpm) and the signaled condition ($\underline{M}$ = 2.1

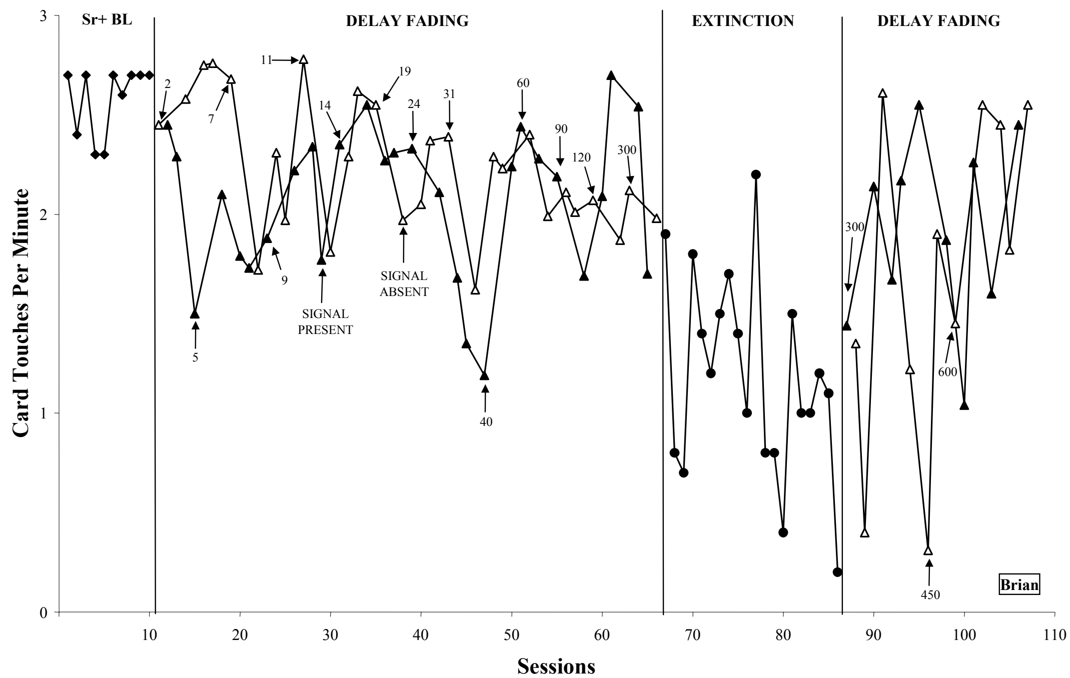

Figure 1. Responses per minute of card touching during baseline, signaled and unsignaled delay fading, and extinction for Brian. Baseline sessions are depicted by the filled diamonds, signaled delay sessions are depicted by the filled triangles, unsignaled delay sessions are depicted by the open triangles, and extinction sessions are depicted by the filled circles.

rpm) until the terminal delay fading value (300 s) was reached. Thus, responding was undifferentiated across the two delay conditions.

Card touching then was exposed to a series of extinction sessions to demonstrate the functional relationship between the behavior and contingent access to food. Response rates gradually decreased across extinction sessions. Signaled and unsignaled delayed reinforcement was again introduced before the behavior decreased further to avoid completely extinguishing the response. Responding was exposed to a 300-s delay to reinforcement in both conditions because responding had maintained at that delay value in the previous exposure to reinforcement. The delay then was increased to 450 s and 600 s to determine if responding would differentiate at larger delays. Rates of card touching were more variable in the unsignaled delay-fading condition than in the signaled condition at the 300-s and 450-s delays. However, levels were similar in both conditions when the delay reached 600 s.

These findings suggested that the signal did not influence responding under delayed reinforcement for Brian. Several possible interpretations can be drawn from the results. First, the gradual increase in the delay to reinforcement may have promoted response maintenance under delayed reinforcement regardless of the presence of the signal. In other words, fading may have increased the efficacy of delayed reinforcement as demonstrated in previous applied studies (e.g., Fisher et al., 2000; Hagopian et al., 1998), and the presence of a signal did not alter responding in the context of the fade. Alternatively, it is possible that the effects of the signal would have been detected if the delay had been increased beyond 600 s. That is, the delay interval may not have been thinned to a large enough value to produce extinction-like effects in the absence of a signal. Finally, it is possible that the signal promoted response maintenance but that interaction effects obscured any differences in responding across conditions. For example, the presence of the signal during one condition of the multielement design may have enhanced response maintenance during the unsignaled condition. Other possible explanations are discussed in more detail below (under General Discussion).

Results and Discussion - Chuck

The results for Chuck are depicted in Figure 2. In the first phase, Chuck engaged in much higher rates of communicative behavior under baseline with immediate reinforcement (*M* = 1.3 rpm) than under extinction (*M* = 0.3

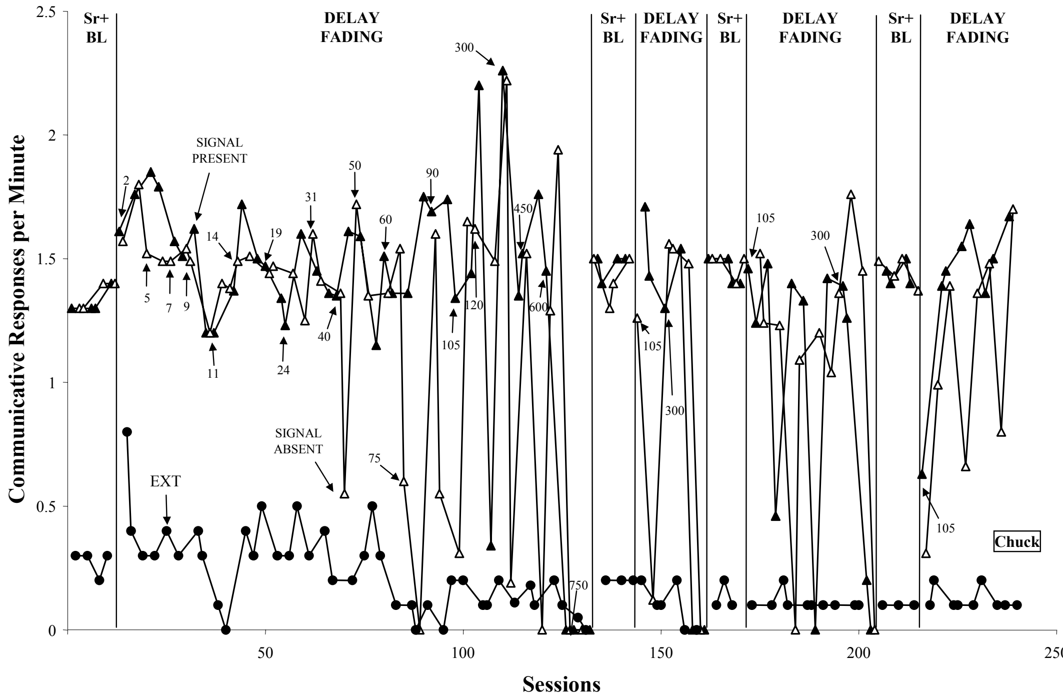

Figure 2. Responses per minute of communicative behavior during baseline, signaled and unsignaled delay fading, and extinction for Chuck. Signaled delay sessions are depicted by the filled triangles, unsignaled delay sessions are depicted by the open triangles, and extinction sessions are depicted by the filled circles.

rpm), demonstrating that the reinforcer was functionally related to the card touch. Thus, beginning with session 13, Chuck’s communicative response was exposed to gradually increasing delays to reinforcement in both the signaled and the unsignaled delay-fading conditions. Rates of responding maintained and were similar in both conditions until the delay value reached 300 s. The delay then was increased to 450 s, 600 s, and 750 s to determine if responding would differentiate at larger delays. Rates of responding were highly variable but similar under the 450-s and 600-s delays and decreased to 0 in both conditions by the 750-s delay. In fact, Chuck did not respond at all under the 750-s delay, suggesting that his behavior was functionally extinguished under the 600-s delay.

Baseline with immediate reinforcement then was introduced to reestablish responding, and rates of the communicative response increased to previous baseline levels. To further evaluate the effects of the signals in the absence of the gradual delay fade, the 105-s delay was introduced. This value was selected because it was the largest delay under which responding was stable in the signaled condition but variable in the unsignaled condition during the previous comparison. Rates generally maintained at the 105-s delay, but extinguished when the delay was increased to 300 s. This effect was replicated after reestablishing responding under baseline and reintroducing the 105-s and 300-s delays. After a final baseline phase, responding maintained at similar levels in the signaled and unsignaled conditions under a 105-s delay.

The presence of the signal did not appear to attenuate the effects of delayed reinforcement for Chuck. In fact, responding repeatedly decreased to 0 at the same delay value under both signaled and unsignaled conditions. As with Brian, it is possible that interaction effects across the two reinforcement delay conditions masked any differences in responding. Other possible interpretations of these findings are discussed in more detail below (see General Discussion).

Results and Discussion – Michele

The results for Michele are depicted in Figure 3. Michele was exposed to baseline (immediate reinforcement) and extinction sessions in a multielement design, followed by a series of extinction sessions. For the purpose of evaluating the results, data from an extinction phase that was conducted as part of communication training immediately prior to the baseline phase also are shown in the figure. (The purpose of implementing extinction prior to baseline was to demonstrate experimental control over the

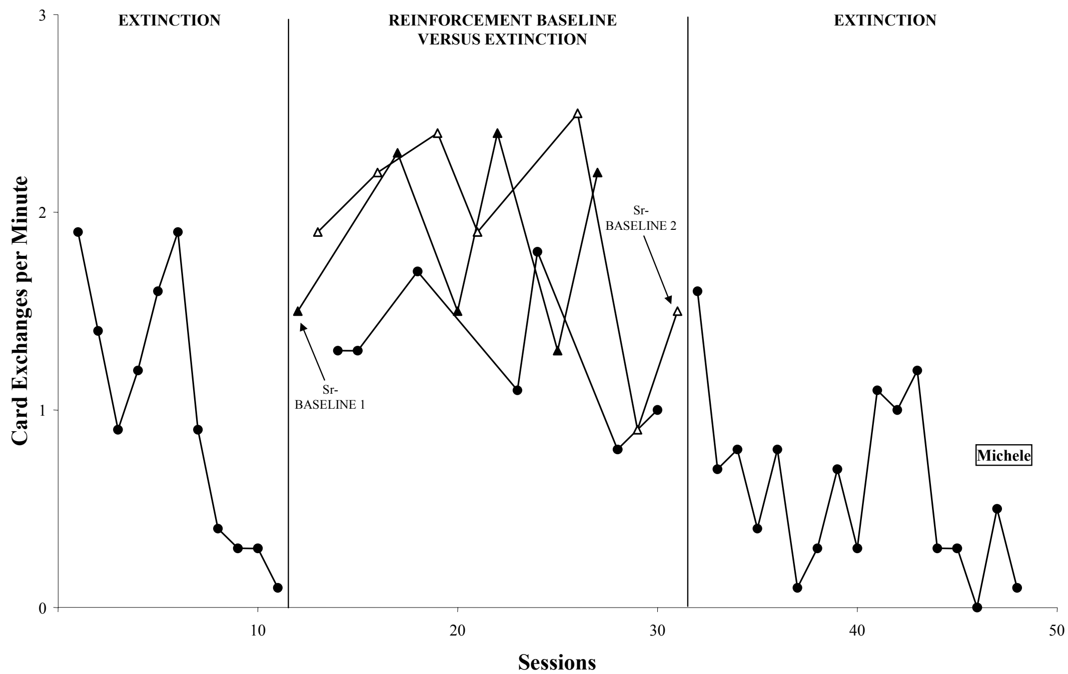

Figure 3. Responses per minute of card exchanges during extinction and reinforcement for Michele. Extinction sessions are depicted by the filled circles, reinforcement condition 1 sessions are depicted by the filled triangles, and reinforcement condition 2 sessions are depicted by the open triangles.

communication response, which decreased to low levels in the final 4 extinction sessions.) The two baseline (reinforcement) conditions differed only with respect to the color of the cardboard stimuli associated with each condition (as described above under Experimental Design). During the multielement comparison, Michele engaged in high rates of card exchanges across the reinforcement and extinction conditions, which suggested that interaction effects were influencing the results. That is, the effects of reinforcement in the baseline conditions appeared to carry over into the extinction condition. Michele's behavior was then exposed to a series of extinction sessions to further evaluate the possibility of interaction effects. Responding decreased to levels similar to those obtained under extinction prior to baseline.

These findings suggested that interaction effects likely would obscure any differences in responding during the delay fade if a multielement design was used. Therefore, the multielement comparison was discontinued for Michele. Results for Michele also highlighted the importance of evaluating the possibility that interaction effects were responsible for the negative findings obtained with Brian and Chuck.

Experiment 2: Unsignaled Versus Signaled Delays To Reinforcement within a Reversal Design

All procedures were identical to those described in Experiment 1 with the exception of the experimental design (all participants) and the delay-fading schedule (Chuck only). The effects of signals were evaluated using an ABACAB design for Brian, an ACABACAB design for Chuck, and an ACABABAC design for Michele (A = baseline, B = signaled delay fading, and C = unsignaled delay fading). The delay-fading schedule for Brian and Michele was identical to that used in Experiment 1 (see Table 1). The delay increased by 20 s every 8 sessions for Chuck. The target terminal delay value was 300 s for all participants. However, reinforcement delay fading was terminated prior to 300 s whenever responding remained below baseline levels for a minimum of 4 consecutive sessions. Communication responses were exposed to a series of extinction sessions whenever responding maintained until the terminal delay was reached.

Michele's behavior was exposed to delay fading for the first time in Experiment 2. Procedures used in the signaled and unsignaled delay-fading conditions were identical to those used in the baseline (reinforcement) condition with the following exceptions. Contingent on the occurrence of a communication response, the therapist continued to present demand trials until the delay expired. In the signaled delay condition, the therapist placed a digital timer on the table while continuing to present instructional trials during the delay. At the end of the delay interval, the timer emitted a beeping tone, and all instructions, instructional materials, and the timer were removed for the 20-s reinforcement interval.

Results and Discussion – Brian

The results for Brian are shown in Figure 4. Rates of card touching were high and stable in baseline (*M* = 2.4 rpm). Responding decreased somewhat relative to baseline under the 2-s signaled delay but maintained until the terminal delay-fading value was reached (300 s). Response rates under the 120-s and 300-s values were similar to those under baseline. Card touching then was exposed to extinction, under which responding decreased to low levels. High levels of card touching were reestablished when food was delivered immediately following each occurrence of the response during the reversal to baseline (*M* = 2.5 rpm). During the unsignaled delay-fading condition, response rates gradually decreased and remained low as the delay was lengthened, so the phase was terminated at the 75-s delay value. Responding was low and variable during the reversal to baseline, but the rates returned to previous baseline

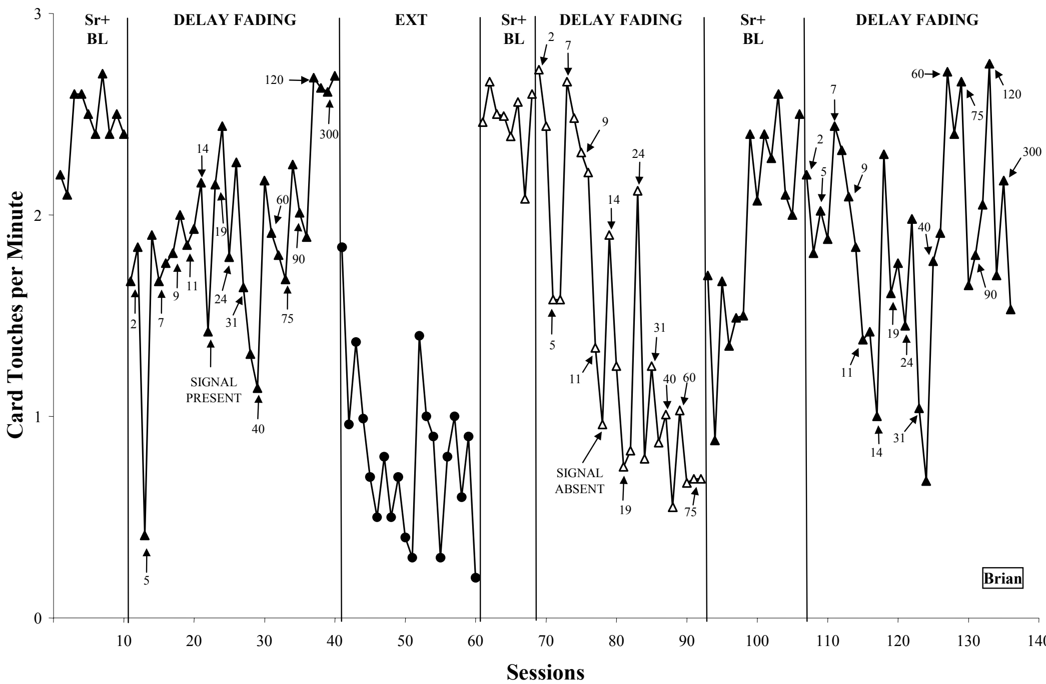

Figure 4. Responses per minute of card touching during signaled delay fading, unsignaled delay fading, and extinction for Brian. Signaled delay sessions are depicted by the filled triangles, unsignaled delay sessions are depicted by the open triangles, and extinction sessions are depicted by the filled circles.

levels during the final 8 sessions of the phase (M = 2.3 rpm). During the second exposure to signaled delay fading, responding was variable but maintained until the terminal delay-fading value was reached.

These results support the hypothesis that interaction effects were responsible for the undifferentiated outcomes in Experiment 1. Brian's responding maintained to the 300-s delay during both exposures to the signaled delay fade, whereas rates were low and variable under relatively short delay values (between 11 s and 75 s) during the unsignaled delay fade.

Results and Discussion – Chuck

The results for Chuck are shown in Figure 5. During baseline, responding was stable across 8 sessions (M = 1.4 rpm). Responding remained generally stable as the delay interval was increased to 80 s under the unsignaled condition, whereupon rates became variable and were much lower for 5 consecutive sessions. Delay fading was terminated, and responding was reestablished during the reversal to baseline (M = 1.5 rpm). During the signaled delay condition, response rates generally maintained near baseline levels until the 100-s delay. Responding abruptly decreased to low levels during the last 3 sessions of the

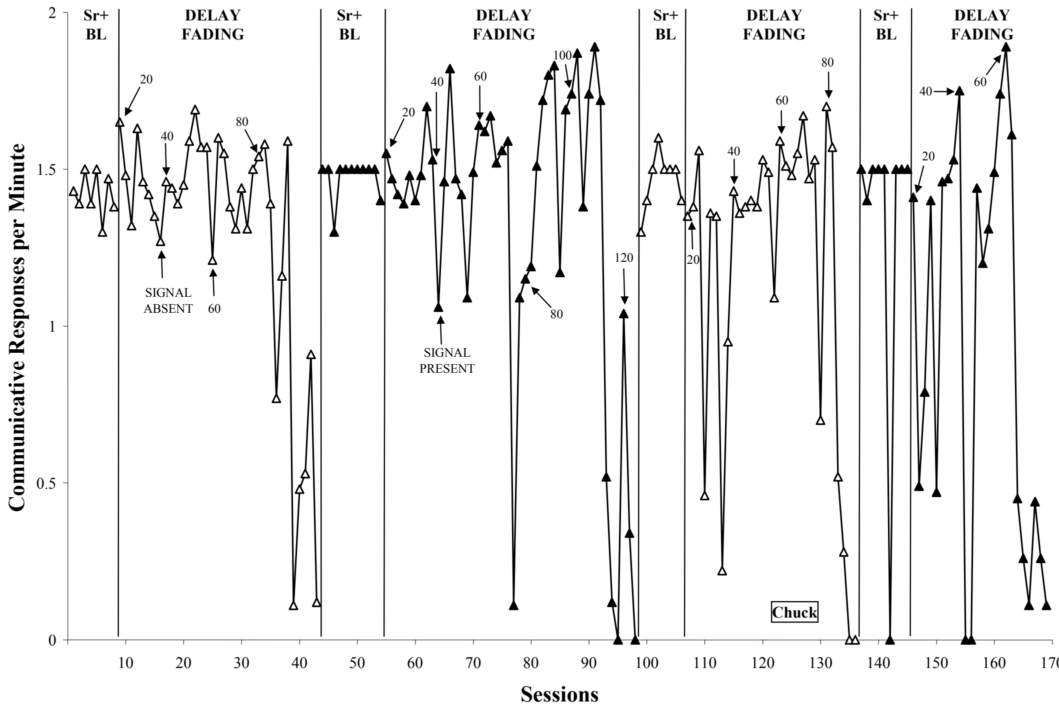

Figure 5. Responses per minute of communicative behavior during baseline, unsignaled delay fading, and signaled delay fading for Chuck. Signaled delay sessions are depicted by the filled triangles, unsignaled delay sessions are depicted by the open triangles, and extinction sessions are depicted by the filled circles.

100-s signaled delay and remained low under the 120-s delay.

Responding then was reestablished under baseline (M = 1.5 rpm) prior to replicating the unsignaled delay condition. Responding was variable but generally maintained until the delay was increased to 80 s, whereupon rates decreased to 0 levels. Following a reversal to baseline (M = 1.3 rpm), responding under the second signaled delay condition was highly variable and decreased to low levels for 6 consecutive sessions under the 60-s delay.

To summarize, Chuck's behavior appeared to extinguish at similar delay values under both signaled and unsignaled delay-fading conditions. These results are similar to those obtained in Experiment 1, despite the fact that a different experimental design and fading schedule was used in Experiment 2. These data do not support the hypothesis that interaction effects were responsible for the negative outcomes obtained in Experiment 1. A number of possible explanations for these findings are discussed in more detail below (see General Discussion).

Results and Discussion - Michele

Results for Michele are presented in Figure 6. Response rates were low during the initial baseline phase

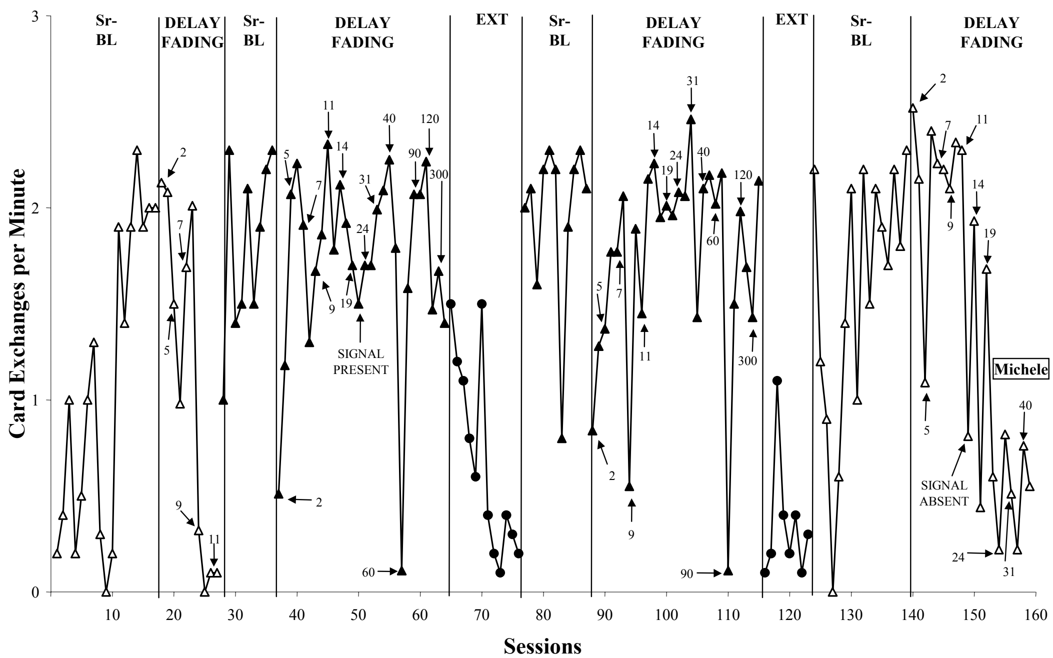

Figure 6. Responses per minute of card exchanges during signaled delay fading, unsignaled delay fading, and extinction for Michele. Signaled delay sessions are depicted by the filled triangles, unsignaled delay sessions are depicted by the open triangles, and extinction sessions are depicted by the filled circles.

but increased and stabilized across the last 7 sessions (M = 1.9 rpm). When the response was exposed to unsignaled delay fading, rates decreased to low levels under the 9-s and 11-s delays. The phase was then terminated because responding had remained low for 4 consecutive sessions. Rates of card exchanges again increased when escape was delivered immediately following the occurrence of the response during the reversal to baseline (M = 1.8 rpm). Throughout signaled delay fading, responding generally maintained within baseline levels until the terminal delay-fading value (300 s) was reached.

Michele’s response then was exposed to extinction so that a similar history would precede each sequence of baseline and delay fading conditions. Under extinction, rates of responding decreased to levels that were similar to those at the 9-s and 11-s delays in the unsignaled delay condition. Baseline rates of card exchanges were reestablished when escape was delivered immediately following the occurrence of the response (M = 2.0 rpm). During the second exposure to signaled delay fading, responding again generally remained within baseline levels until the terminal delay-fading value (300 s) was reached, thus replicating the effect of signaled delay fading. Michele’s card exchange response was again exposed to extinction, and rates decreased to low levels. Responding was variable during the first 10 baseline sessions but remained relatively stable in the final 8 sessions (M = 2.0 rpm). Finally, when card exchanges were exposed to unsignaled delay fading, rates of responding remained somewhat stable until the 11-s delay. Responding then began to decrease and remained low for 7 consecutive sessions as the delay was increased to 40 s. Michele was not exposed to the complete fading schedule because responding did not maintain at levels comparable to those with smaller delay values in this phase.

These results suggested that the presence of a signal promoted response maintenance under gradually increasing delays to reinforcement. Responding maintained until the terminal delay value was reached in each exposure to the signaled delay fade. When the delay was unsignaled, responding decreased to low levels relatively early in the fading process (i.e., when the delay was less than 30 s).

General Discussion

The effects of signals on responding during delays to reinforcement were evaluated. When signaled and unsignaled delay-fading conditions were compared in a multielement design (Experiment 1), the presence of a signal did not produce higher response rates or greater response persistence than when a signal was not present. This comparison was terminated prematurely for the third participant (Michele) because responding was undifferentiated across the baseline (immediate reinforcement) and extinction conditions, suggesting that interaction effects would have influenced the findings if the analysis had continued. When signaled and unsignaled delay-fading conditions were compared in a reversal design (Experiment 2), responding for 2 of 3 participants (Brian and Michele) appeared to persist at lengthier reinforcement delay values when signals were used. These results suggested that, for 2 participants, (a) interaction effects across the rapidly alternated conditions of the multielement design influenced responding in Experiment 1, and that (b) the presence of signals facilitated response maintenance during delayed reinforcement.

These findings are important from an applied perspective. Parents, teachers, and caregivers often are taught to implement treatments that have been evaluated under tightly controlled (i.e., analogue) settings. These interventions may fail in the natural environment due to treatment challenges (e.g., poor or inconsistent procedural integrity) that are not accounted for in treatment development (Vollmer et al., 1999). For example, FCT may be highly effective in an analogue setting when reinforcement is delivered immediately following each communication response. However, caregivers may be unable or unwilling to provide immediate reinforcement when the treatment is implemented in the natural environment. In previous applied studies, responding failed to maintain under delayed reinforcement or maintained under relatively small delays (e.g., Fisher et al., 2000; Hagopian et al., 1998; Hanley et al., 2001).

A number of basic studies have demonstrated that signals during delays to reinforcement will increase the likelihood of response maintenance under delayed reinforcement (e.g., Schaal & Branch, 1988; 1990). However, no studies have attempted to establish the generality of this basic relation through systematic replication with clinical populations and problems. The purpose of the current study was to provide an initial bridge between basic and applied work by replicating basic research findings on signaled delayed reinforcement. As such, the effects of signals were evaluated in the context of FCT, a popular treatment for reducing problem behavior and increasing the communication repertoires of individuals with developmental disabilities. Moreover, the relationship between signals and responding was evaluated during the course of a delay-fading procedure similar to that used in previous applied studies on delayed reinforcement during FCT (e.g., Fisher et al., 2000; Hagopian et al., 1998). These gradual fading procedures are somewhat effective but have generally failed to produce response maintenance at delay intervals exceeding 30 s. One goal of the current study was to determine whether signals could improve typical fading methods.

Nevertheless, the basic relation between signals and responding was not demonstrated for any participant in Experiment 1 and for 1 participant (Chuck) in Experiment 2. When studies produce negative outcomes, it is important to develop and evaluate potential reasons why an independent variable did not produce an effect. Several hypotheses can be developed to explain the negative results for each participant in Experiment 1. First, the signal simply may not have influenced responding for Brian or Chuck. Alternatively, for Brian, whose behavior maintained under both signaled and unsignaled delay fading, it is possible that the effects of the signal would have been detected if the delay had been increased beyond 600 s. That is, the delay interval may not have been thinned to a large enough value to produce extinction-like effects in the absence of a signal. Brian's caregivers considered 600 s to be more than a reasonable delay for Brian to access a small edible, so the interval was not increased further.

Third, signals may not have influenced responding within the context of the delay fading procedure. Subjects in basic studies on delayed reinforcement typically were exposed to many more trials and fewer delay intervals, and any change in the delay was dependent upon stable responding under the current delay value (e.g., Schaal & Branch, 1988; 1990). During the initial multielement comparison, the participants’ behavior had limited opportunity to come under the control of any particular delay value because the number of exposures at each delay value was predetermined (2 sessions), and the interval was increased independent of responding. Prolonged exposure to the signals at a particular delay value may have been a better test of signal effects, particularly because increased exposure may have facilitated discrimination between conditions. It is also possible that the signals could not further enhance the efficacy of the gradual delay fade. The potential impact of the fading procedure was evaluated to a limited degree in Experiment 1 when 300-s, 450-s, 600-s delays were re-implemented for Brian and when 105-s and 300-s delays were re-implemented for Chuck. Furthermore, results for Chuck were similar in both experiments, even though each delay value was implemented for 8 sessions in Experiment 2.

Fourth, it is possible that an inadequate number of pairings occurred between the signal and the reinforcer because the signal was not present during baseline (when reinforcement was delivered immediately) and because the delay was progressively increased throughout the signaled condition. Some authors have suggested that signals function as conditioned reinforcers (Ferster, 1953; Schaal & Branch, 1988). Because the delay was increased every two sessions, the signal may not have been sufficiently paired with the reinforcer (i.e., snack, video, or escape) to become a conditioned reinforcer.

Finally, it is possible that the signals promoted response maintenance in Experiment 1 but that interaction effects obscured any differences in responding across conditions. For example, the presence of the signal during one condition of the multielement design could have enhanced response maintenance during the unsignaled condition. This explanation could account for the results of Brian's comparison. Alternatively, for Chuck, the absence of the signal during one condition could have negatively impacted response maintenance during the signaled condition. Results of the baseline phase for Michele in Experiment 1 suggested that interaction effects between the reinforcement and extinction conditions influenced her responding. During both exposures to a series of extinction sessions, Michele’s card exchange behavior conformed to the schedule (i.e., card exchange rates decreased to near-zero). When extinction sessions were alternated with reinforcement sessions, the rate of card exchanges increased and maintained under extinction. Together, results for the 3 participants indicated that an alternative experimental design would be warranted for further evaluation of signals.

In applied research, treatment comparisons typically are conducted using either the multielement design or the reversal design. The multielement design is especially ideal for rapidly comparing two or more independent variables even though results are vulnerable to interaction effects (Higgins Hains, & Baer, 1989). The reversal design is not only more cumbersome for treatment comparisons, but it may introduce sequence effects, in which responding during one condition is influenced by prior exposure to another condition. Sequence effects are a particular concern when studying the effects of signals because prior exposure to gradually increasing delays can enhance the efficacy of delayed reinforcement in the absence of signals (e.g., Fisher et al., 2000; Hagopian et al., 1998). Thus, the multielement design was selected for Experiment 1 because it minimizes sequence effects.

Nevertheless, Vollmer et al. (1995) showed that the reversal design can be useful for determining whether interaction effects influenced the outcome of a multielement comparison. Thus, the purpose of Experiment 2 was to (a) evaluate the original hypothesis regarding the effects of signals during delayed reinforcement, and (b) examine the possibility that interaction effects were responsible for the negative results in Experiment 1. The use of the reversal design in Experiment 2 eliminated the potential for interaction effects that may have produced undifferentiated responding. When Brian’s card touching response was exposed to signaled and unsignaled delay fading in the context of a reversal design, responding (a) maintained until the 300-s delay in the first exposure to the signaled condition, (b) decreased to low levels by the

75-s delay in the unsignaled condition, and (c) maintained until the 300-s delay in the second exposure to the signaled condition. Similar results were obtained for Michele, who was exposed to the signaled and unsignaled conditions in a different order (unsignaled, signaled, signaled, unsignaled). Responding decreased to low levels by the 11-s delay (first unsignaled phase) and 24-s delay (second unsignaled phase) in the absence of a signal yet maintained until the 300-s delay when a signal was used. It seems unlikely that sequence effects could explain both response maintenance in the signaled condition and response decrement in the unsignaled condition for Brian and Michele. Therefore, it is reasonable to assume that interaction effects were at least partially responsible for the undifferentiated outcomes found in Experiment 1.

Results for Chuck, however, did not support the hypothesis that interaction effects were responsible for undifferentiated responding in Experiment 1. The data from both experiments indicated that his behavior was sensitive to the reinforcement contingencies but not to the presence of the signal. Responding under the signaled and unsignaled conditions maintained and extinguished at similar delay values in both Experiments 1 and 2, despite the fact that different experimental designs and fading schedules were used. It is unclear why the relation between signals and responding that has been reported in basic studies and that appeared to occur for the other 2 participants in Experiment 2 was not replicated with Chuck.

It is possible that other aspects of the methodology were responsible for the negative outcomes obtained in this study. As described above, the delay fading procedure used in the study differed markedly from that used in basic research on signals and delayed reinforcement. Other procedural differences, such as the reinforcement schedule and type of reinforcer used, may have contributed to the somewhat disparate findings between those in basic research and those found in the current studies. For example, food reinforcers were used in basic studies, whereas Brian, Chuck, and Michele responded for food, video, and escape from demands, respectively.

In addition, most basic studies employed closed economies (Tustin, 1994), in which subjects must respond during sessions to access stimuli that are not available outside of the experimental setting. Although the subjects in Schaal and Branch (1988; 1990) received supplemental feedings of health grit (which was different from the food available during sessions), they were provided with the minimum amount of extra-session food to maintain 80% of their free-feeding weights. At the very least, this sort of economy would produce extraordinary levels of deprivation and establish food as a potent reinforcer for the target response. It is unlikely that the participants in the current study and subjects in basic studies experienced comparable levels of deprivation. Similar (and likely substitutable) reinforcers were almost certainly available outside of sessions for Brian and Chuck (i.e., other snack foods and videos were likely available for Brian and Chuck, respectively, in settings other than the experimental setting; see Green & Freed, 1993 for a discussion of the substitutability of reinforcers and its effect on behavior). Signals may have better controlled responding if the specific reinforcers and other substitutable stimuli were not available outside of the experimental context.

The schedule of reinforcement also differed from those typically used in basic research on signaled delayed reinforcement. Schaal and Branch (1988; 1990) employed variable interval (VI) reinforcement schedules, under which the first response that occurred after the passage of some time interval produced the reinforcer. Responding that is maintained on VI schedules may be more sensitive to signals during delayed reinforcement than responding that is maintained on a CRF schedule. The CRF schedule was used for two reasons. First, ratio schedules rather than interval schedules are more likely to be used as part of treatment with functional communication training. Second, CRF schedules maintain a strong response-reinforcer relationship because reinforcement is delivered after every occurrence of a response. Using CRF schedules in the current study was consistent with past research on FCT treatments and was sound experimentally because only one treatment challenge (i.e., delayed reinforcement) was introduced. Nevertheless, reinforcement schedules may interact with the basic relationship between signals and delayed reinforcement.

Other limitations of the study warrant further discussion. The difference in responding under signaled and unsignaled reinforcement was not completely replicated for Brian in Experiment 2 because a BCB design was used (B = signaled reinforcement; C = unsignaled reinforcement). This is problematic because the logic of the reversal design necessitates replication of the experimental effect (Cooper, Heron, & Heward, 1987). Results would have been strengthened by including a replication of the unsignaled delay fading condition. Some authors have used ABA or BAB designs (A = baseline, B = treatment) when it is impossible, unreasonable, or inconvenient to conduct a complete reversal design (Geller, Paterson, & Talbot, 1982). Brian was due to be discharged from the program, which limited the number of possible treatment sessions. An equivalent of the BAB design was selected (i.e., Brian was exposed to unsignaled delay fading only once) because the signaled condition was conceptualized as the “treatment” relative to the unsignaled condition. Thus, the benefits of the signal could be evaluated by replicating the "B" phase immediately prior to his discharge. However, conclusions about the effects of the signal must remain tentative.

Finally, the effects of signals during delayed reinforcement were examined with only 3 participants. Although the results of Experiment 2 suggested that signals may facilitate response maintenance during delayed reinforcement, any conclusions regarding the efficacy of signals should be tempered until this effect is replicated with more individuals.

There are several avenues for future research. Future studies should determine if some of the procedures used in the current study interacted with the effects of the signals. As noted above, different results may have been obtained if the delay fade had followed the progression used in basic studies. For example, in Schaal and Branch (1988), delay values were 1 s, 3 s, 9 s, and 27 s, and stable responding was used as a criterion for increasing the delays. The effects of a signal may be less apparent if a gradual delay fade promotes response maintenance. Furthermore, allowing responding to stabilize before increasing the delay may provide a better test for signal effects. Stable responding would indicate if and when the behavior has come under the control of the conditions. The multielement comparison may have produced undifferentiated responding because the delay increased so rapidly that responding did not come under the control of the signal at any particular delay value.

The type of stimuli used as signals may have affected the results and should be evaluated in future studies. The signals for Brian, Chuck, and Michele were all different, and it is possible that some stimuli may be more effective as a signal. Any stimulus change that occurs during the delay to reinforcement could potentially function as a signal and thus facilitate response maintenance. The stimulus (or stimulus change) should be as salient as possible and should be present only in the experimental context to maximize the conditioning effect. Anecdotal evidence suggested that the stimuli were salient for all participants in the current study. For example, Brian often grabbed the container and helped the therapist shake it. Chuck often attempted to physically guide the therapist to place the tape into the VCR before the delay interval expired. Finally, Michele often pointed at and attempted to touch the digital timer, and she sometimes clapped and smiled when the timer emitted a tone at the end of the delay interval.

Some authors have hypothesized that signals function as conditioned reinforcers during delayed reinforcement (Ferster, 1953; Fisher et al., 2000). As noted above, a potential limitation of the current study was that a conditioned-reinforcement effect may not have been established. In further research, the stimulus should be paired with immediate reinforcement during baseline. Additional pairings could be arranged during the early stages of delay fading, and the conditioned effect of the signal could be directly evaluated. For example, the signal could be delivered contingent on the occurrence of some other (arbitrary) response to determine if the signal produces a reinforcement effect.

Finally, future researchers should continue to conduct bridge studies. The goal of bridge studies is to determine the extent to which the variables that affect responding in the laboratory operate in a similar manner in naturalistic environments (Fisher & Mazur, 1997), thus attempting to link basic and applied research and ultimately to discover general behavioral relations. Mace (1996) argued that the "collection of useful behavioral principles is incomplete and that we should continue to expand this collection of broadly useful behavioral principles to address some fundamental questions that remain unanswered" (pg. 558). One way to expand this collection of principles is to establish the generality of basic behavioral relations through systematic replication with clinical problems and populations.

Many authors have discussed the potential benefits of linking basic and applied research (e.g., Fisher & Mazur, 1997; Lattal & Perone, 1998; Mace, 1996; Mace & Wacker, 1994; Stromer, McComas, & Rehfeldt, 2000). Recent comprehensive reviews of basic and applied research on important learning principles, such as extinction (e.g., Lerman & Iwata, 1996), punishment (e.g., Lerman & Vorndran, 2002), and reinforcement (e.g., Vollmer & Hackenberg, 2001), provide a blueprint for developing further research on factors that may improve treatments for individuals with developmental disabilities. Studies linking basic and applied research have produced useful treatments for noncompliance (Mace et al., 1988), methods for shifting responding among alternatives (Lalli, Mauro, & Mace, 2000), and identification of relationships between competing reinforcement contingencies (Hagopian, Crockett, van Stone, DeLeon, & Bowman, 2000). In one example of this type of research, Mace et al. (1988) attempted to replicate the basic principle of behavioral momentum (Nevin, Mandell, & Atak, 1983). This replication led to the *hi-p* treatment for noncompliance for individuals with developmental disabilities. Linking basic and applied research has been fruitful conceptually, empirically, and socially. Continuing to extend the results of basic research may expand the current technology of behavior change.

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